Watergardens as Stormwater Infrastructure in Portland, Oregon

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Abstract

Watergardens are aspects of the built environment that emulate nature's processes. Water is not a feature unto itself, but an integral element of the site and architecture. Watergardens are a synergetic result of landscape, biology, architecture and engineering. The principle of integrating water in urban design introduces water as a friendly companion, but always with attention to its potential power and negative aspects. This symbiotic design principle includes soil and vegetation within the urban hardscape. Trees, plants and soil are employed to function with water in urban spaces previously not used for stormwater management. We might call this a new paradigm, urban-nature, not at the expense of our human habitat … but as enhancement of this habitat … earth, water, plants … all have an artful place with people in the urban context. Documentation of tests, monitoring data, costs and observations show the viability of the techniques discussed. Application of this new paradigm will result in lower development costs, more cost effective retrofits, improved livability and a more natural urban environment.

Introduction

Urban development provides the essentials of human community life. Usually within this human community exists some degree of nature. These human essentials are, to a large extent, forms of impervious surfaces and pipes. Stormwater runoff, the physical phase of precipitation after it falls in the urban community, is almost foreign to the natural environment. The cause of this runoff comes from the impervious surfaces needed within the urban community. To reverse, mitigate or eliminate the negative effects of stormwater runoff new ways of designing or retro-designing the urban community are being explored and tested. Many of these new ideas are actually modern applications of age-old approaches, which for some reason had faded away. Maybe the resurgent interest in bringing aspects of nature back into the community is caused by some of the federal laws governing water, air and threatened species. Certainly within the Pacific Northwest water and nature are synonymous with salmon and forests. And, what is becoming apparent is the building blocks of nature are also the building blocks of a healthy urban community. These new ideas begin to take shape in the form of urban design techniques: methods of integrating water with land and vegetation. Watergardens, or perhaps better stated as eco-gardens, are an aesthetic and cost effective approach to design with water.

In Portland ideas that re-green or mitigate the effects of impervious surfaces are being developed. These approaches include development of a healthy <u>urban</u> forest, re-vegetation and preservation of riparian corridors and habitat, identification and removal of un-necessary impervious surfaces, improved street designs to reduce environmental impacts, improved zoning codes to reduce hard surfaces, and identification and implementation of green/sustainable building and site design practices. The physical characteristics of impervious surfaces are essentially - rooftops and pavement. These surfaces are at best environmental dead zones, but are certainly not benign as they have other than direct water impacts such as contributing to urban heat island conditions, smog, loss of wildlife and habitat, increased carbon dioxide, and reduced oxygen and photosynthesis.

So what is the paradigm that best describes these new ideas or approaches? Simply stated it is the careful integration of water with site and architectural design. The applications of design elements allow the urban hydrology to better mimic nature. The design elements are those usually within the landscape architects purview, including soil, plants/trees, rock and wood with water added.

This paper introduces scientific information obtained either from direct testing or by recently published technical literature. Next, design techniques are presented with reference to their functions and benefits. Projects that have employed one or more of these techniques are presented. Each demonstration project offers built examples. And it is expected that these techniques will improve with each new application. Projects are discussed with a description of the site, techniques employed and commentary on what works and what doesn't.

Studies: Pacific Northwest Precipitation and Hydrology

Portland Rainfall Analysis

Most precipitation in the Pacific Northwest occurs in the form of small storms. Using U.S. Weather Service data, an analysis of 24-hour precipitation events was conducted. Storms were divided into sizes from 0-0.2", 0.2-0.4", 0.4-0.6" and so on, up to and including the largest storms during the past 16 years. To simplify the analysis at the risk of accuracy, a 24-hour event was based on calendar day rain totals. Fig. I.6.1 indicates that on average 145 days per year had storm events, or calendar days of rain, of 1.0" or less. These storm events accounted for 81% of the average annual rainfall. This characteristic of precipitation is an important part of understanding how to better manage urban runoff and pollutants associated with these numerous events. Limitations of this study include the lack of distinction between calendar days, i.e. 0.2" could fall at midnight and another 0.8" could fall in the hours immediately following on the next day. Albeit simple, it is not encumbered by the debate of what antecedent dry period should be used to define the beginning and end of a "storm" event. Even so, the information is relatively consistent with other studies, such as those presented at the Salmon in the City Conference, (see citations).

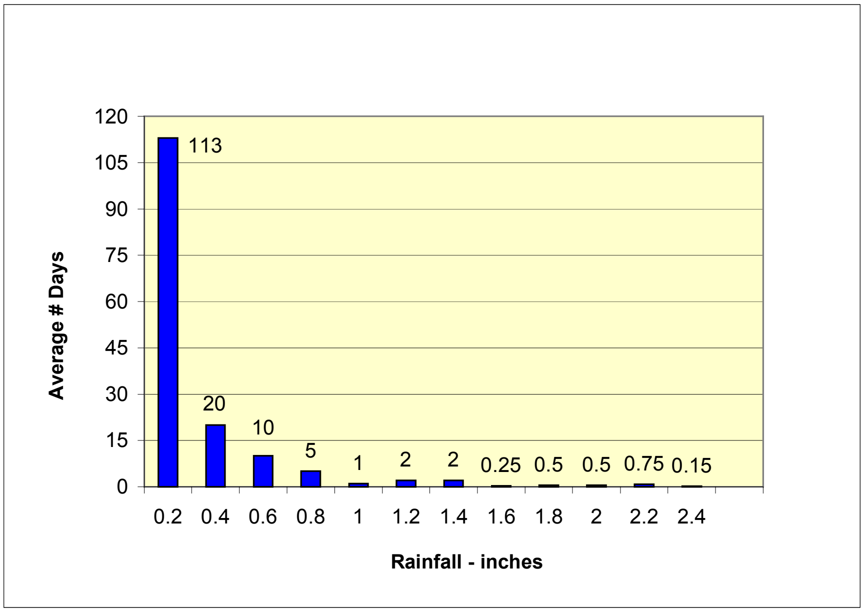


Figure I.6.1

Comparison of pre-development forest versus post-development peak flows and volumes

An analysis of rainfall distribution was conducted to determine the pre and post runoff from storm events using 0.1" increments, starting with 0.1"/24 hour events and continuing at every additional 0.1" up to 2.4" (the Portland 2 year event). The Santa Barbara Urban Hydrograph (SBUH) method was employed for these calculations. Here again this may not be the most accurate method to use, but it is currently approved by the city for sizing storm facilities. A hypothetical site of 5 acres was used, with predevelopment assumed to be a forest condition with a curve number CN70. Postdevelopment was 3 acres of impervious surface with a curve number CN98 and the other two acres assumed to be left undisturbed, but hydrologically connected to the new storm system. Results for the predevelopment condition indicate that <u>no</u> runoff occurs for storms of 0.0 - 0.8" 24 hour events. Fig. I.6.2 shows that predevelopment peak flows do not begin until at least a 0.9" event occurs and then have peak flow rates of up to 0.14 cfs (cubic feet per second) for the 2 year 24 hour event. For postdevelopment conditions, runoff occurs with the first 0.1" event. For 0.3" events, the post peak flow is 0.16 cfs, and then increases to more than 10 times the predevelopment peak for the 2-year event. Fig. I.6.3 shows a comparison of runoff volumes, with predevelopment at <u>zero</u> cf. (cubic feet) for all storms up to 0.8" and 7,396 cf. for the 2-year event. Post development discharge volumes were 383 cf. for the 0.1" event and 27,810 cf. for the 2-year event. In the predevelopment conditions little, if any, runoff occurs for storms of less than 1.0". In the postdevelopment condition runoff occurs with each event of 0.1" or more.

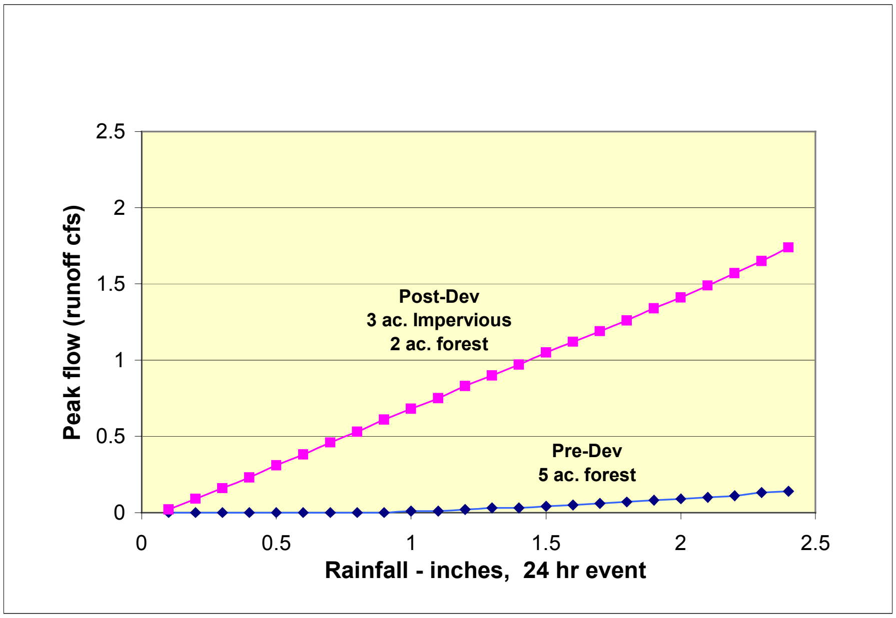


Figure I.6.2

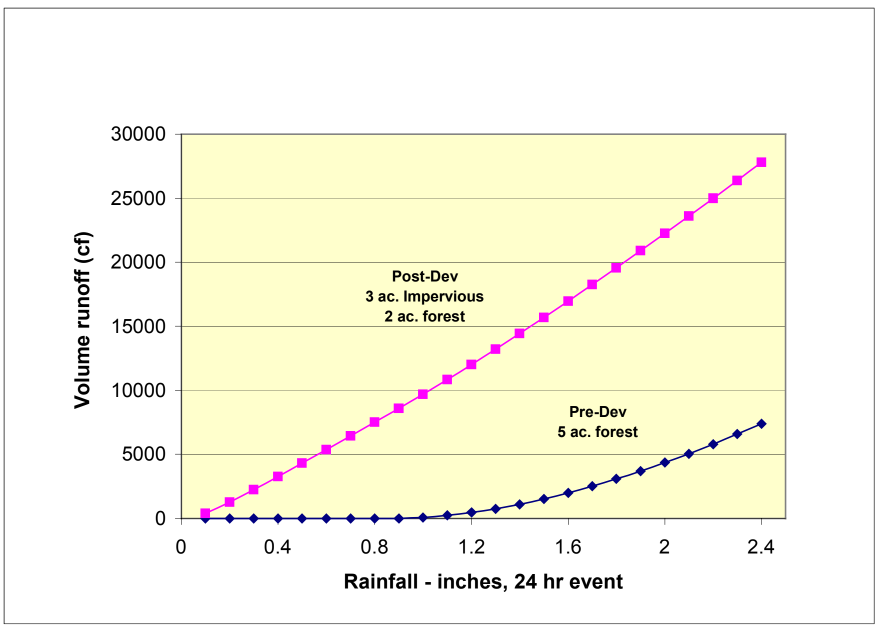


Figure I.6.3

Bolton and Watts (1998) state, "Very little precipitation ends up as overland flow in a mature, undisturbed forest." At the same conference, Beyrlein and Brascher state that in the Puget Sound area with annual rainfall at 40.7", 18.8" evapotranspirates and only 0.1" precipitation becomes surface runoff. Based on the above SBUH analysis, prior to development, no surface runoff occurs in a conifer forest for over 100 storm events per year, on average. This would also indicate that the energy of water within streams is only affected by surface runoff occasionally.

In addition, the pollutants carried into streams from surface flows would also occur occasionally. Surface runoff for post-development conditions occurs more than 100 times a year and carries not only natural occurring pollutants, but also human generated pollutants. Energy from the storms is also conveyed to the stream with peak flows equal to the 2 year event occurring with >0.3” events. Basically, there's a "whole-lotta" runoff and pollutants that did not previously occur. And it is happening almost every time it rains. Note; conventional detention methods (vaults and ponds) would only reduce the energy of the higher peaks, but not the 100 times per year they occur. Another factor of detention would be the extended duration of time needed to get the higher volumes out of the facility.

In a post-development condition, significant flow, volume and energy are entering urban streams. Since pre-development pollutant loadings are zero for these predominant events, then any post-development discharge, regardless of the constituent concentration, would be greater than the pre-development reference point. In the post-development condition, urbanized sites discharge pollutant loads of many orders of magnitude above pre-development conditions and occurs more often. If there is no runoff, then where does the rainfall go? According to Bolton and Watts, and others, much of it is intercepted in the tree foliage, bark and branches, which then evaporates. Some rain falls to the forest floor, where it is absorbed and then makes its way into the ground and gradually seeps into streams.

Portland, Bureau of Environmental Services (BES) Test Swales

These swales were constructed to test various design characteristics, which, at the time, had not been documented by anyone else (at least not to the knowledge of BES). Issues of concern include pollutant removal or capture efficiencies of different plant species, soils, and flow attenuation and velocities. Additional issues may be tested in the future. Both swales are identical in geometric shape and soil type. Tests to date have been based on a difference of vegetation in each swale. One swale is planted with native grasses and forbes and the other swale is planted with turf grasses. The turf grass was mowed regularly and the native vegetation was left to grow naturally. A portion of stormwater runoff from a 50-acre urban area is pumped into each swale with almost identical volumes. Flow meters measure the flow at the end of each swale. Three pollutant samples are taken at each swale every 30 minutes during a storm event and then combined for analysis. A total of 6 events over the last two years have been sampled. To date results indicate the following:

Runoff attenuation occurs in both swales. The swale with native vegetation retains up to 41% of the flow and the turf swale retains about 27%. No identifiable conditions exist to explain the difference and it is assumed, at this time, that the native vegetation and lack of mowing allows the swale to facilitate infiltration. This may be due to the robustness of the root systems and presence of more organic material in the native vegetation swale vs. the turf grass swale. Fig. I.6.4 shows the flow comparison for each storm event.

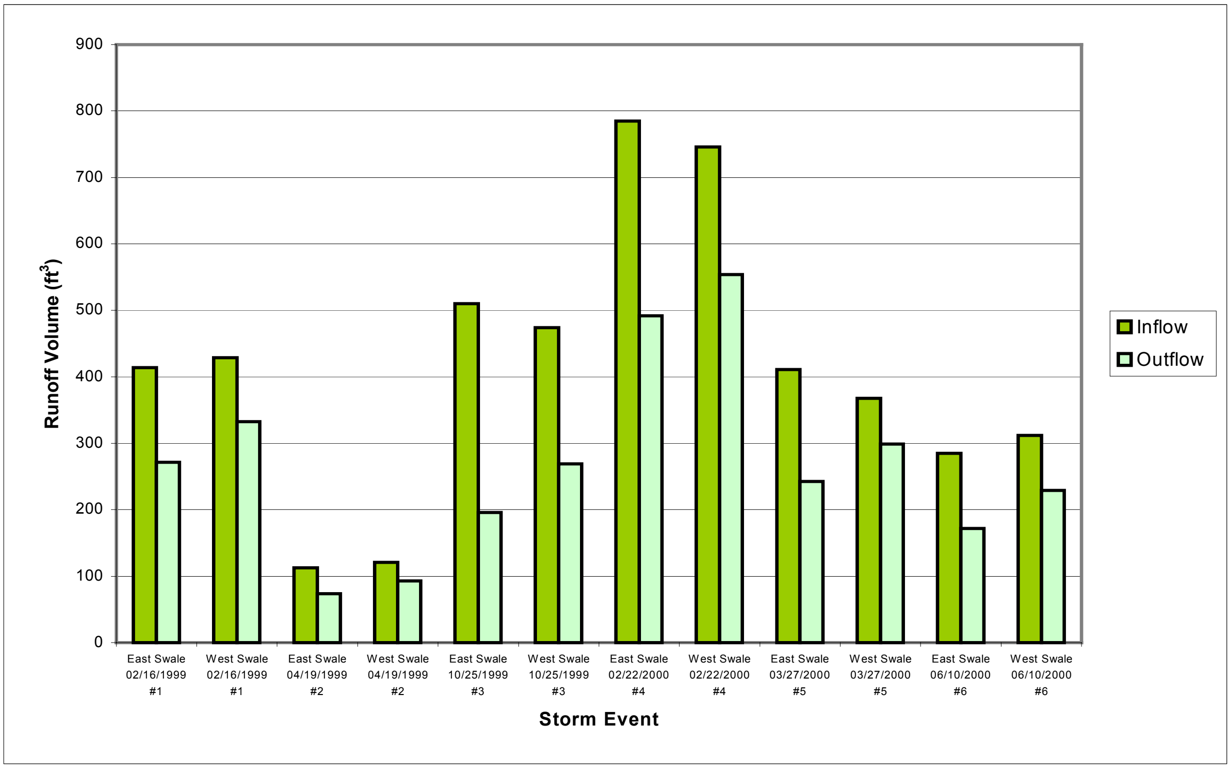


Figure I.6.4

Pollutant removal efficiency is good during all seasons, but is better for warm season load reductions. Generally, the swale planted with native grasses captures more pollutants than the turf swale, except for phosphorous. This may be due to accumulation of organic matter in the swale, whereas grass clippings were removed from the turf swale. Recent storms monitored don't show a measurable difference in swale performance even though the turf has not been mowed for over a year and the inflow has been increased from 0.04 cfs to 0.08 cfs. Fig. I.6.5 shows that both swales continue to perform relatively well.

Summary

Pollutant removal relative to concentrations is good; for example, average total suspended solids (TSS) removal is 59% for turf and 68% for native vegetation. When loads are calculated based on runoff volume captured in each swale and concentration removal, the TSS removal percentages are 69% for turf and 81% native vegetation. Vegetation maintenance is not necessarily required. A messy or somewhat natural looking planting does not indicate the stormwater management functions have been impaired.

Grab Parameters	East Swale[1]	West Swale[2]
pH (FIELD)	3%	4%
DISSOLVED OXYGEN (FIELD)	20%	25%
TEMPERATURE	4%	3%
CONDUCTIVITY (FIELD)	-13%	-3%
TOTAL OIL & GREASE	32%	31%
NON-POLAR OIL & GREASE	50%	34%
Composite Parameters		
TOTAL SUSPENDED SOLIDS	81%	69%
TOTAL DISSOLVED SOLIDS	28%	18%
TOTAL SOLIDS	60%	51%
COD	65%	52%
TOTAL KJELDAHL NITROGEN (TKN)	54%	40%
TOTAL PHOSPHORUS	50%	38%
O-PHOSPHATE-PHOSPHORUS, DISS	-75%	-45%
NITRATE-NITROGEN	16%	8%
HARDNESS	46%	33%
CADMIUM, TOTAL	73%	61%
COPPER, TOTAL	65%	53%
LEAD, TOTAL	72%	62%
ZINC, TOTAL	76%	63%
CADMIUM, DISSOLVED	47%	50%
COPPER, DISSOLVED	52%	38%
LEAD, DISSOLVED	53%	36%
ZINC, DISSOLVED	64%	48%

Figure I.6.5

Design Techniques or "Green Solutions"

Nationwide, techniques are being developed by many who are helping to shape this new paradigm **(Chapters I.1 and I.5).** Water, soil and vegetation are purposely introduced into site and building elements previously isolated from each other. There are four basic functions that result: water soaking into soil/vegetation, water flowing over soil/vegetation and inanimate objects, water transpired by vegetation, and precipitation intercepted by vegetation and evaporated (water even evaporates during dry periods of storm events see BES tree study 2001). The combination of these functions is often advantageous to achieve better water distribution. Pollutant capture is achieved by water having to filter through the soil and/or vegetation. Atmospheric pollutants are captured in plant foliage and then trapped in the soil, where many of them have an opportunity to break down. All of these approaches allow runoff to be diffused, which also allows pollutants to be distributed in the landscape instead of concentrated. Increases in urban air and water temperature are minimized or eliminated by shade on impervious surfaces and in the case of ecoroofs, nearly all precipitation is retained during warm season months (May–October). The physical forms of these techniques are almost infinite, but are described here as:

Infiltration garden - Figure I.6.6
Stormwater Planters - Figure I.6.13 and Figure I.6.14
Vegetative Filters – Figure I.6.28
Landscape swales - Figure I.6.11
Ecoroofs - Figure I.6.18

Portland demonstration projects

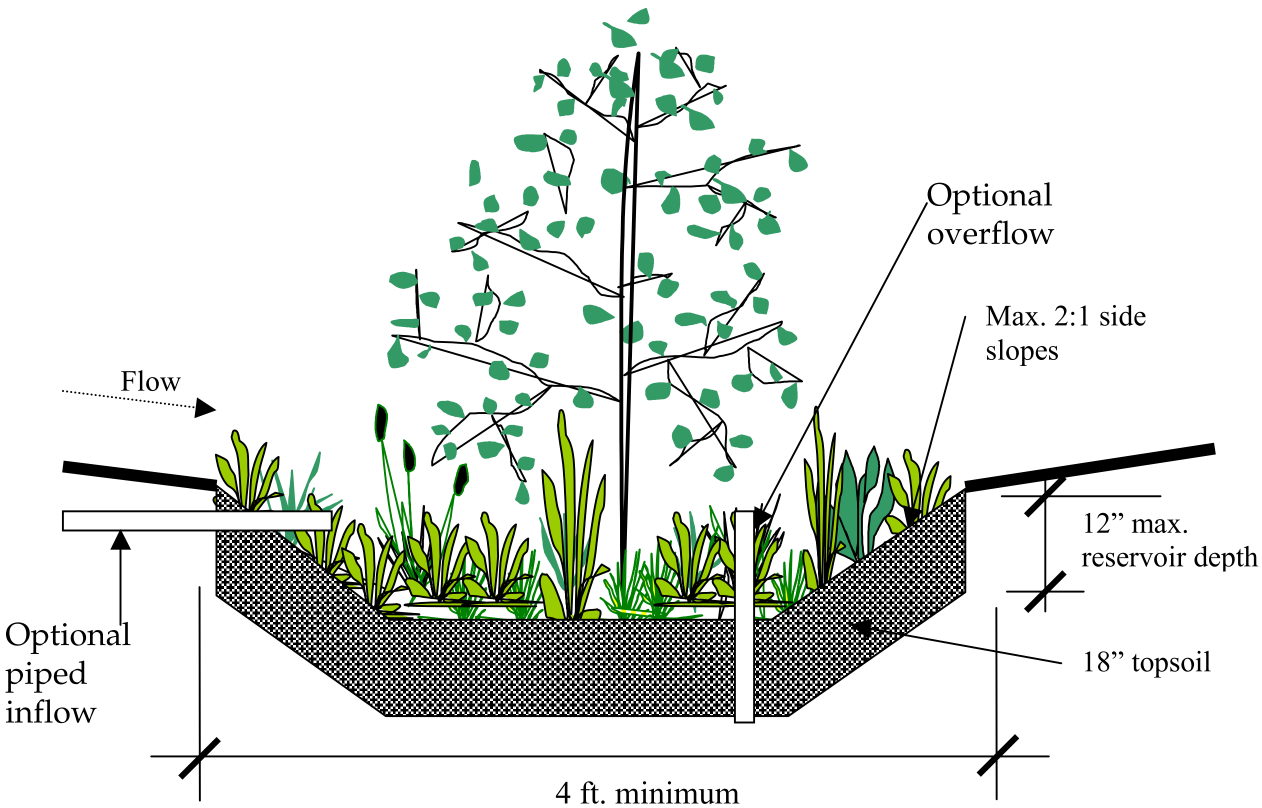
Buckman Heights Apartments

A redevelopment project in the combined sewer area designed in 1996 and opened in 1998. The site's previous use was for a new car dealership parking lot. The site is 2 acres, with a 150 unit, 4-story apartment building and some surface parking and underbuilding parking. The project has many environmental attributes including car-sharing for the tenants. The Owner, Prendergast Associates, wanted to do their part to remove the site's runoff from the combined sewer system. The buildings are organized around a main courtyard; the traditional layout is articulated with low seating walls off the sidewalk and two large planting beds designed as landscape infiltration areas to filter and absorb the storm water from the building's downspouts. The parking areas are designed with care and detail to reduce the presence of the automobile and absorb the water runoff from the paved surface.

Landscape infiltration

Courtyard. Figure I.6.7 shows two 18 ft x 45 ft infiltration gardens integrated with the site. The gardens were designed to accept runoff from the rooftops and the surrounding courtyard paved areas to flow into the vegetation. The planter area tapers from 6" along the perimeter of the surrounding walkways to 18" at the center. Moisture tolerant plants of spirea, iris, Oregon grape and astibe were planted within a Japanese Holly border. Figure I.6.8 displays an overflow pipe set 9" above the bottom of the basin. Runoff enters the landscape infiltration area and soaks into the soil, except for large storms that flow out the overflow. This keeps the area at a maximum depth of water during storms of 9" with percolation rates estimated at 2" per hour; the area is expected to drain within 5 hours.

Figure I.6.6



Section Not to Scale

Description *Landscape infiltration areas can be integrated into the site landscaping. The design can be formal or informal in character. They may be used in courtyards, parking lots or where other planting areas are available. Although the area is saturated during storm events, infiltration occurs quickly.*

Stormwater Management Function and Sizing *The system works by holding runoff and allowing pollutants to settle as the runoff infiltrates. Flow and volume are also managed with these facilities. Allows evapotranspiration, groundwater recharge and retains warm weather runoff. Depending on soil type & infiltration rate this facility may provide 10–25 year event disposal. Using above proportions size at 0.045 x impervious area for WQ storm.*

General specifications *Acceptable soil types A & B. Minimum soil infiltration rate of 2 inches per hour. Facility storage depth may vary from 2-12". Filters can be planted with a variety of trees, shrubs, and ground covers, including grasses appropriate for periodic inundation. Freeboard not required.*

Figure I.6.7

Figure I.6.8

What have we learned? Aesthetically it is a very pleasing design. Based on visual observations, infiltration rates appear to be increasing. Infiltration tests will be conducted this spring to confirm these observations. If true, then the overflow inlet can be raised several inches to allow more runoff to be infiltrated. Vegetation appears healthy and is growing well. Pruning is done once a year in the fall to maintain the overall desired aesthetic. From a functional perspective the pruning could be reduced. No fertilizers or pesticides are anticipated to be needed, although the entire site has an irrigation system. Piping from the downspouts to the planter has a tendency to clog with sediments from the roofing materials and tree leaves. This requires at least once a year cleaning to maintain good drainage. However, during a very intense 1.4"/3 hour storm on October 1, 2000 the pipes were full and runoff simply overflowed across the lawn and walkways into the planter. Two alternatives, and probably better designs, would have been shallow surface channels integrated with the walkway design or larger pipes.

Parking lot. Figure I.6.9 shows the uniquely designed landscape infiltration perimeter. Perimeter landscaping is required by city code, for a project like this it requires a 5 ft wide strip the entire length of the parking lot, 200 ft. The lot was one of the first to use substandard dimensions with a 20 ft wide aisle and 17 ft long x 8.5 ft wide stalls. Parking is at 90 degrees. What is unique about this integrated landscape is the lack of a freeboard (precautionary measure to contain flows). When considering the configuration and grading of the site, a freeboard was not needed to protect property or people. This allowed a smooth transition from the pavement edge into the planting area. Runoff flows into the landscape via curb cuts and then infiltrates into the relatively porous soil. There is a 2" storage capacity for runoff as it soaks in or for large storm flows to move by displacement toward two inlets at each end of the strip that drain into underground dry wells. Plantings include only Red Sunset Maple trees (*Acer rubrum* 'red sunset') and Oregon Grape as a hedge. Approximately 8,000 sf (square feet) of concrete surface drains into the landscape, which is about 1,000 sf in area. It is estimated that this area will infiltrate the 10 year storm event (3.2"/24hrs).

Figure I.6.9

Figure I.6.10

What have we learned? *The plantings look good and the runoff is captured in the landscape area. To date, visual observations have indicated the area will hold at least a 2 year storm event (2.4"/24hrs) as occurred in Nov 1998. In one area the pavement was not sloped at the specified 2% gradient and causes some ponding in the corner of one car stall. Grinding the existing curb cut about ¾" will allow the water to drain-off. The lack of a freeboard has not posed any concerns. Figure I.6.11 shows one of the curb cuts that must be kept clear to allow flow passage. These curb cuts have not been cleaned since installation and are still relatively unobstructed.*

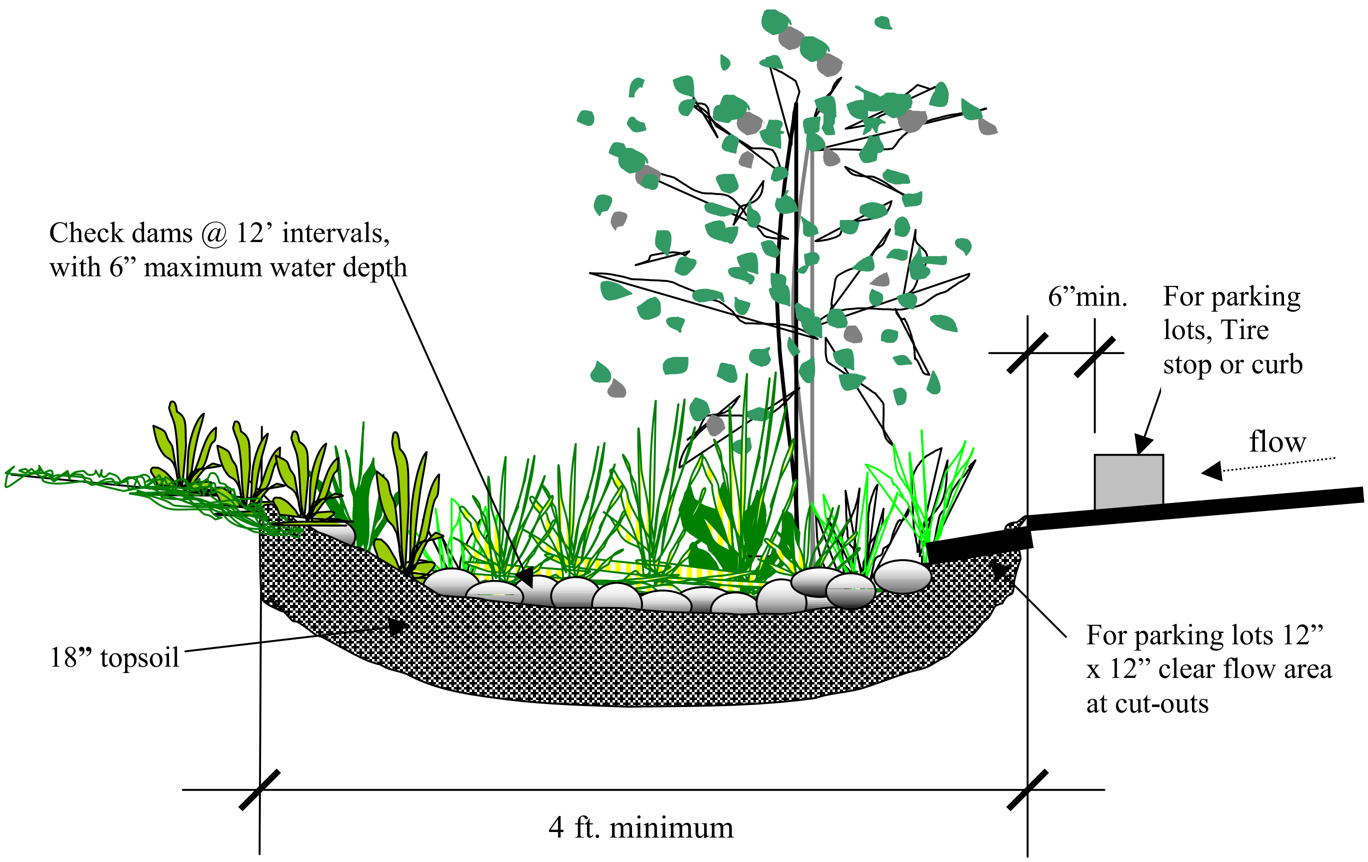
Buckman Terrace Apartments and Commercial

Buckman Terrace is another redevelopment project by Prendergast Associates and is across the street from Buckman Heights. The project was designed in 1997 and opened in 1999. This is a 0.8-acre site with 150 apartment units, with all under building parking and a 1,500 sf commercial section in a 4-story structure. The building also has car sharing and numerous other environmental attributes. An Ecoroof has been installed on the commercial portion and another at the main entrance of the building. Landscape planters are being used on the east side and a landscape swale has been installed on the west side of the building. The landscape techniques integrate lush, moisture tolerant planting with the function of stormwater quality and environmental enhancement.

Landscape swales

Westside swale. Figure I.6.12 shows the westside swale adjacent to the building where all roof downspouts discharge. Approximately 13,000 sf of rooftop drains into a 300 ft swale. The swale is 6 ft wide and 3" deep, it has rock check dams every 15 ft. The swale is sized to convey the 25 year storm event flows, but also to provide detention of all storms up to the 10 years event. These storms are detained behind the check dams. All flows, which exceed the infiltration capacity of the soil, discharge to a catch basin at the downstream end of the swale. A pea gravel mulch was used to slow the flow and provide opportunities for sediment deposition and some infiltration. The swale gradient is approximately 2% until it reaches the last 100 ft where it increases to 4%. Purposefully excluded from the design was the standard 12" freeboard. This was done for two reasons: first the added safety of a freeboard was not needed since there is no possibility of damage to the building or adjacent property; second was aesthetics, because of the narrow area a 12" deeper swale would have been unsightly and dangerous. Plantings include; sedges, miscanthus, spirea, Oregon grape and Japanese iris.

Figure I.6.11



Section Not to Scale

Description *Landscape swales are planting areas with a slight depression of up to 6" that allow runoff to enter and infiltrate and flow through. They are usually long and narrow in width, which makes them well suited for parking lots and other narrow landscape spaces. Swales are constructed with a variety of trees, shrubs, grasses, and ground cover, depending on soil.*

Stormwater Management Function and Sizing *Swales capture pollutants as runoff is detained and absorbed in the soil, vegetation and organic matter. Using above proportions size at 0.05 x impervious area. Detention is provided for storms up to the 10-year event. Swales help mitigate runoff temperatures by retaining most of the runoff in warm seasons. Groundwater recharge occurs as check dams facilitate infiltration.*

General Specifications *Acceptable for all soil types.. Minimum swale length is 20 ft. Maximum slope is 6%. Clay soils shall be amended with 50% sandy loam in the top 18" of the swale. Check dams shall be of durable, non-toxic materials- i.e., rock, brick, and old concrete. Check dams shall be width of swale x 3-5" height. Swales using these design criteria will not need to include a bypass of larger storms. Liners are not needed unless required for groundwater protection or to protect building foundations. Freeboard not required.*

Figure I.6.12

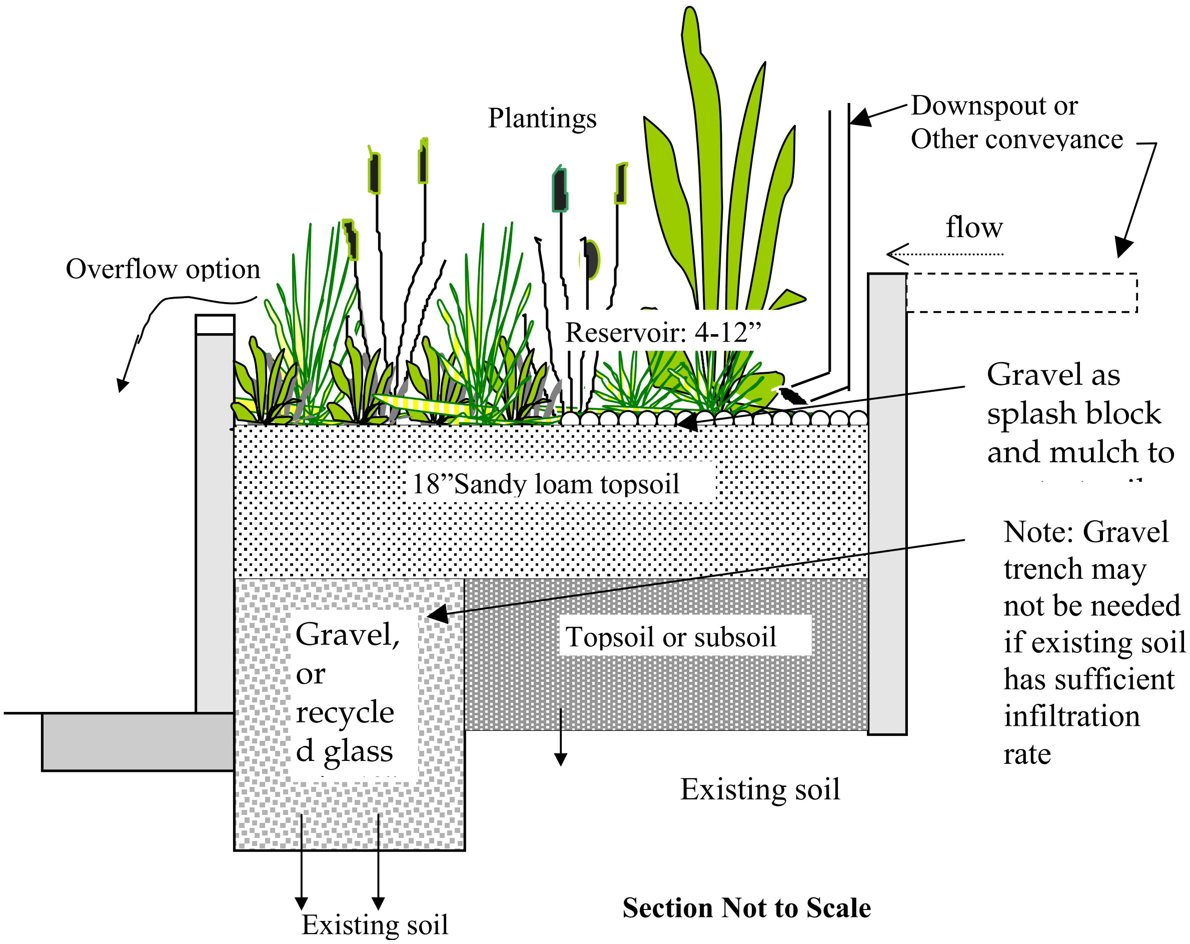
What have we learned? The plantings are attractive and add considerable interest to this side of the building. Visual observations immediately after a large storm event (1.4 inches/ 3 hours) were conducted in October 1, 2000. Most of the flow soaked into the soil, except at the steeper downstream 4% sloped section where it entered the catch basin. Design and construction quality is important for good water management. The check dams were in-correctly constructed parallel to the flow (they were supposed to be perpendicular), which caused peak flows to bypass and erode part of the pea gravel on the downstream section. The 4% section only had clumps of miscanthus grasses planted in a single row and should have had 3 rows with triangular spacing. The pea gravel has worked successfully as mulch to protect the swale and help filter flows.

Stormwater planters

Eastside planters. Two designs were used here; Figure I.6.15 shows the north section planter is at grade and somewhat inconspicuous next to the building. Figure I.6.16 shows the raised planters in the south section at 18-36” above grade. Figure I.6.17 shows that runoff is directed into the planters via scuppers from the roof. Gravel soakage trenches accept water as it filters through the upper soil/ vegetation portion of the planter. Plantings include Japanese spurge, iris, vine maple and Oregon grape. The planters have more surface area than required for Portland conditions and thus the reservoir space is only 2” deep.

What have we learned? Aesthetically the design is equal to the original concepts considered without the use of water. Water is very visible to the tenants as they walk by. Because the soakage trench was within 8 feet of the building foundation, quite an effort was required by the owner and his consultants to get building bureau approval. If the facility had been only 2 feet further away, no special approval would have been required. In tight urban settings like this the “Portland CD” planter version is desired by the building bureau. The CD unit is not designed to allow infiltration, other than some incidental amounts. Although very beautiful, the non-native plants might not perform as well as some native moisture loving species.

Figure I.6.13

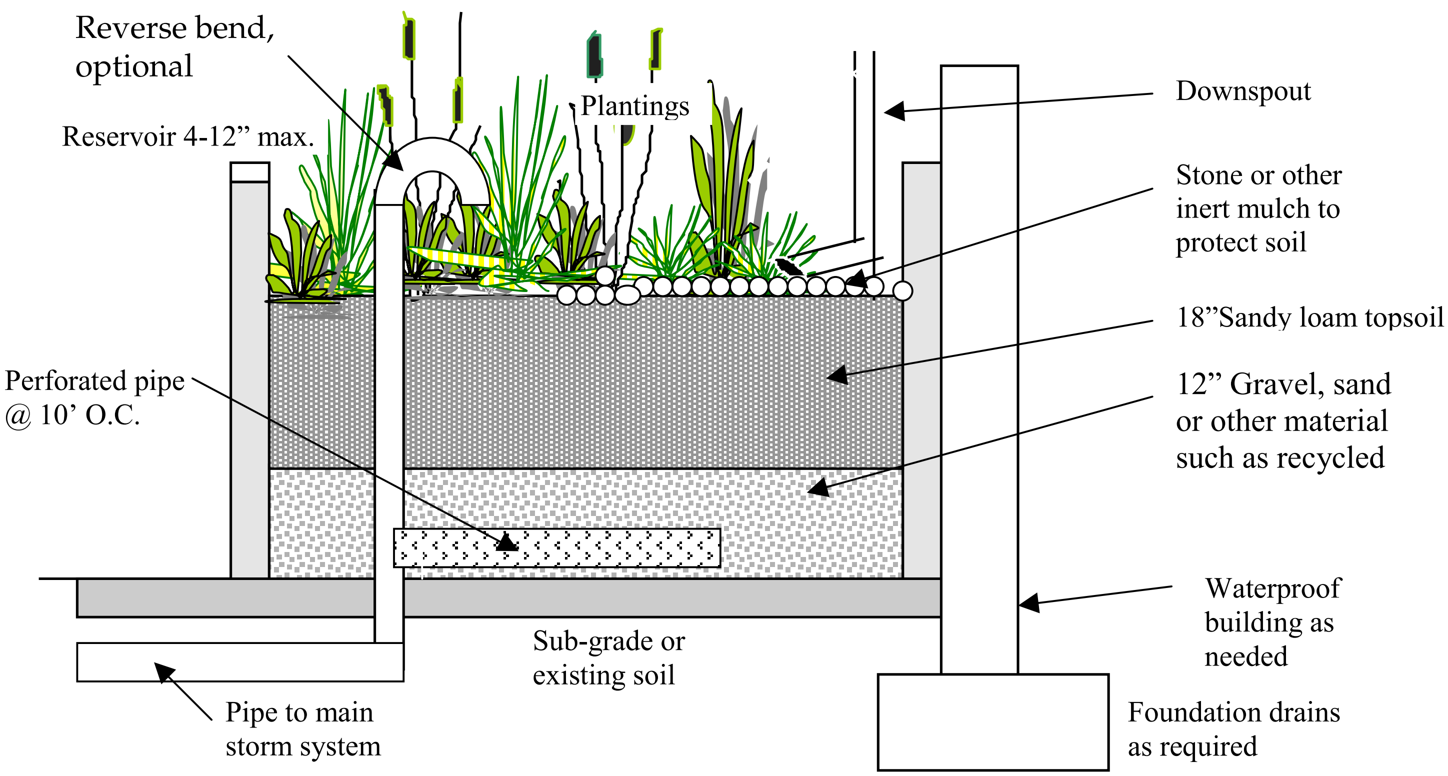


Description *Planter AB is designed with a pervious bottom. The planter is used where infiltration is desirables. Planters are excellent for dense urban development.*

Stormwater Management Functions and Sizing *Planter AB is designed to allow runoff to filter through the planter soils and vegetation (thus capturing pollutants) and then infiltrate into the native soils (flow control). The planter is sized to accept runoff and temporarily store the water in a reservoir on top of the soil. Water quality (WQ) sizing, associated with the 18” topsoil, is for a 0.9” 24/hr storm event. To calculate; use impervious area square feet (sf) x .045 = reservoir cubic feet (cf) of storage required. The infiltration gravel area can be designed to accommodate any storm event.*

General specifications *Acceptable soil types A & B. There are numerous design variations. The planters shall be designed to allow captured runoff to drain out in 2-6 hours after a storm event. Plantings shall be appropriate for moist and seasonally dry conditions, and can include rushes, reeds, sedges, iris, dogwood, currants, and numerous other shrubs, trees, and herbs/grasses. Topsoil shall have a minimum infiltration rate of 2”/hr. Sand/gravel area may not be required if existing soil has at least 5”/hr. infiltration rate. The sand/gravel trench width, depth and length are to be determined by a qualified professional. Minimum planter width is 30”; there is no minimum length or required shape. The structural elements of the planters shall be stone, concrete, brick, wood, or other durable material. If treated wood is used it shall not leach out any toxic chemicals. Planters within 10 ft of structure may require special approval from the local building agency.*

Figure I.6.14



Section Not to Scale

Description *Planter CD is designed with an impervious bottom or is placed on an impervious surface. This planter is used where infiltration is not possible or desirable, such as unstable slopes or brownfields. Planters are excellent for dense urban development.*

Stormwater Management Function and Sizing *Pollutant reduction is achieved as the water filters through the soil; flow control is obtained by storing the water in a reservoir above the soil. Nominal infiltration can be allowed if soils and other geotechnical issues are addressed. The planter is sized to accept runoff and temporarily store the water in a reservoir on top of the soil. Water quality (WQ) sizing, associated with the 18" topsoil, is for a 0.9" 24/hr storm event. To calculate; use impervious area square feet (sf) x .05 = reservoir cubic feet (cf) of storage required.*

General specifications *Acceptable for all soil types. There are numerous planter design variations. The planters shall be designed to hold water for no more than 4-6 hours after a storm event. Plantings shall be appropriate for moist and seasonally dry conditions, and can include rushes, reeds, sedges, iris, dogwood, currants, and numerous other shrubs, trees, and herbs/grasses. Minimum planter width is 18"; there is no minimum length or required shape. Topsoil shall have a minimum infiltration rate of 2"/hr. Sand/gravel shall have a minimum infiltration rate of 5"/hr. The structural elements of the planters shall be stone, concrete, brick, wood, or other durable material. If treated wood is used it shall not leach out any toxic chemicals. Irrigation is optional, although plant viability shall be maintained.*

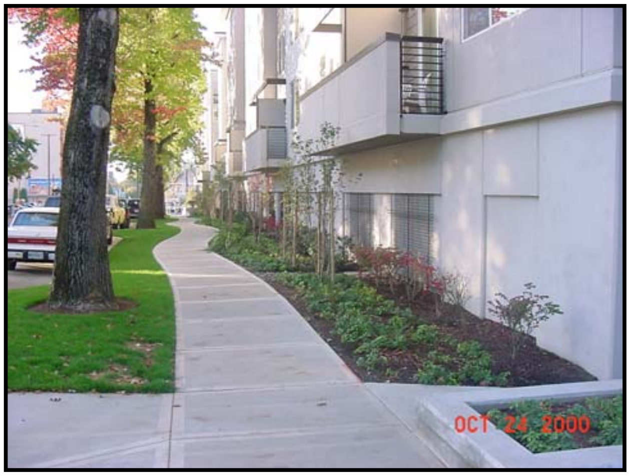


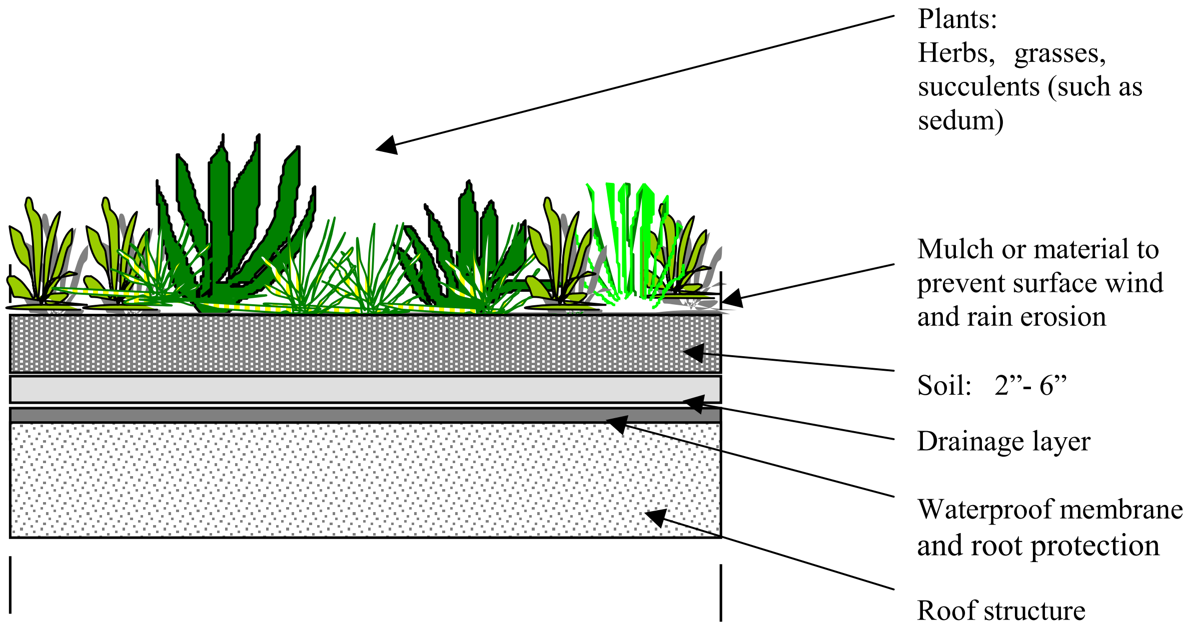
Figure I.6.15

Figure I.6.16

Figure I.6.17

Ecoroofs. The entire building has a roof area of approximately 25,000 sf and the building is constructed with sufficient weight capacity to hold an ecoroof. As a test, ecoroofs were placed on two sections, Figure I.6.19 shows a 200 sf ecoroof above the front entrance. A small 25 sf rooftop above drains into the ecoroof. Figure I.6.20 shows the main ecoroof over 1500 SF of commercial space, which has full solar exposure. An additional 750 sf of impervious roof drains into the main ecoroof. Figure I.6.21 shows a close-up of Oregon sedum on the entrance ecoroof, which is also planted with sword fern, licorice fern and white stonecrop. It is on the eastside and is in the shade of a north-facing wall. Both were planted in March 2000. The commercial ecoroof was planted with two species of Oregon sedum, various wildflowers, native grasses and a few licorice ferns. Grasses and wildflowers were planted from seed, and mulch was hand broadcast to protect against wind erosion. Figure I.6.22 shows a Globe flower (*Gilia capitata*) blooming on the main ecoroof. An irrigation system has not been installed for either ecoroof. The soil profile is 20 lb. per sf when saturated and is 4"deep. American Hydrotech waterproof membrane and reservoir drain system was used. BES staff specified the soil mix and vegetation.

Figure I.6.18



Section Not to Scale

Description *An ecoroof is a lightweight roof system of waterproofing material with a thin soil layer and protective cover of vegetation. The ecoroof can be used in place of a traditional roof.*

Stormwater Management Function and Sizing *The ecoroof captures and then evapotranspirates 10-100% of precipitation, depending on the season. Roof runoff rates are significantly retarded because the rain must first soak through the soil before running off the roof. An Ecoroof provides peak flow detention for storms up to the 10-year event. Ecoroofs mitigate runoff temperatures by retaining most of the runoff in warm seasons. Groundwater recharge can occur where roof drains flow to landscape areas. Sizing is equal to the square footage of ecoroof.*

General Specifications *Quality waterproof material appropriate for Ecoroof application. Soil of adequate fertility and drainage capacity at depths of 2-6 inches. Building structure adequate to hold an additional 10-25 psf weight. Vegetation shall be self-sustaining plants, without the need for fertilizers or pesticides. Soil coverage to prevent erosion must be established immediately upon installation, either by using mulch or protective blanket or vegetation mats (sod). Ninety-percent plant coverage shall be achieved within 2 years. Temporary irrigation to establish plants is recommended. Permanent irrigation systems using potable water may be used, but the water application shall not exceed 0.25 inches every 10 days for June-September season. Irrigation is not needed from Oct.-May. Projects are encouraged to have alternative means of irrigation, such as cooling tower condensate or other non-potable sources. For roof slopes greater than 10% measures (such as geotextile webbing, and sleepers) shall be used to prevent soil slippage.*

Figure I.6.19

Figure I.6.20

Figure I.6.21

Figure I.6.22

Figure I.6.23

Figure I.6.24

Figure I.6.25

What have we learned? Grasses and wildflowers achieve a graceful, flowing appearance. It's reminiscent of Eastern Oregon or Midwestern American prairie. During the warm season, storm event runoff was visually observed to be very low or non-existent. The ecoroof had capacity to hold much of the additional flow from the other roofs. During winter storms runoff occurs often, but is detained. Many of the plants survived or re-seeded with only one hand watering. Although no maintenance was conducted this year, it appears the grasses will need to be mowed at least once a year. Should the owner prefer a different plant association sedum might be added at some future time? It is very important to assure good vegetation coverage; especially over the lightweight soils to prevent wind erosion.

On another ecoroof project, the Hamilton Apartments in downtown Portland, almost an inch of soil was lost to wind erosion. Depending on the initial planting scheme, cover crops, such as common clover, may provide excellent soil coverage. Which is what happened on a section of the ecoroof. Water from air conditioning condensate is a possible source of free, non-potable water for irrigation. Condensate flows were significant during the hottest part of the summer, with flows measured at 12 oz per minute in the afternoon and 6 oz. per min. in the late evening. This might prove to be a free source of irrigation water, if considered during the design phase. On this project BES is testing to determine characteristics of planting methods, measurement of runoff flows and precipitation, and viability of soil and vegetation. Other issues may be addressed in the future. Figure I.6.23 shows the southeast quadrant of the ecoroof. Figure I.6.24 shows one of several stonecrop species in bloom last August. Figure I.6.25 shows some of the moss that colonized certain areas of exposed soil and helped reduce wind and soil erosion. Light weight soils must be fully covered to prevent erosion. Garland Co. waterproof membrane and planting design was used on this project.

BES Water Pollution Control Laboratory

The project site was previously a 6-acre industrial site along the eastbank of the Willamette River and adjacent to a city park on its north side. It was used for industrial activities for almost 100 years. The upland neighborhoods are a mixture of old residential and industrial land uses, with new residential conversion and in-fill occurring rapidly. The area was served by a combined sewer system that overflowed into the Willamette River about 75 times annually. BES installed a $5.4 million separated stormwater pipe system for 50-acres that drains to the water garden. At the time, treatment of separated stormwater was not required, but it was decided that a water quality pond would be constructed to reduce pollutants entering the river. Neighborhood citizens were very concerned that BES was going to create a problem pond. However, after considerable effort by the citizens and BES, a mutually agreeable plan was prepared; and a Water Garden as it was eventually named was constructed.

Simultaneously, BES was preparing to build a new Water Pollution Control Laboratory, on another portion of the site. The new building would have laboratory, office and field operations space, and a public meeting room for the neighborhood and others. The building footprint is approximately 12,000 sf, with parking for 60 cars and 1.5 acres was allocated for the water garden. About one acre still remains vacant for potential expansion. The parking lots were designed with landscape swales (see Test Swales above). The project was designed in 1995 and opened for use in 1997. Combining the best of the artistic and the utilitarian, the design transformed this once industrial site into a meaningfully sculpted landscape, integrated with ecological processes. Each component of the site speaks to the inherent poetry of water and its role in our environment.

The Water Garden (pond) From the very beginning this facility had to be special. Attention to aesthetics and integration with the neighborhood was essential. The upland catchment contains approximately 40 acres of impervious surfaces and 10-acres of mixed pervious surfaces. Some of these include gravel yards for storage of heavy equipment. The pond was designed to accommodate the peak flow from a 0.83”/24hour storm event, with a diversion structure to bypass large storm flows directly to the river (bypass flows assumed to carry lower pollutant concentrations). Figures I.6.26 and Figure I.6.27 show the focal point of the design, a 1-acre pond formed from two converging circles. Elements include a circular stone wall to house the pond outlet structure, a 100 foot long rock filled concrete shute that conveys flow, but yet provide an artful sculpture during dry weather, and a lushly planted pondscape that is integrated with the building landscape design and the adjacent park. The curvilinear flume in the upper cell is reminiscent of a glacial moraine. It slows the stormwater while directing it into the detention cells. The cells are planted with a variety of aquatic and emergent plant material that naturally facilitate sedimentation and biofiltration of pollutants. Circular weep holes on both sides of the flume uniquely display the flow of water. The plantings include a mix of native and non-native species, and include Oregon Ash, Red Alder, Red Maple, several grasses, Redtwig dogwood, Douglas spirea, Oregon Grape and numerous wetland species. An observation platform was designed, as an extension of the main spine of the building, and extends over the water. Three monitoring stations were set up to measure flows and pollutants to determine pond efficiency.

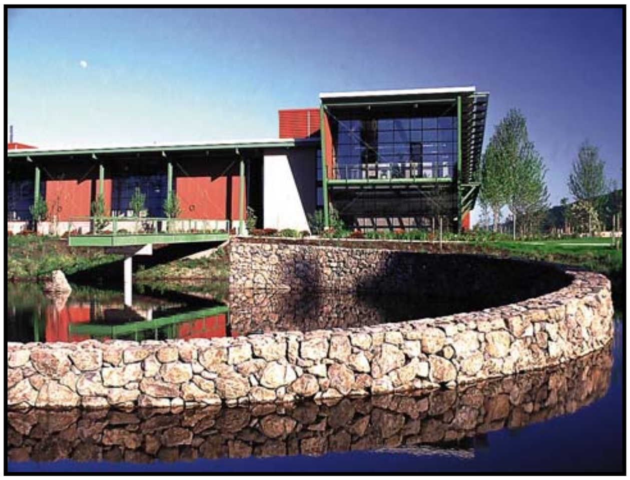


Figure I.6.26

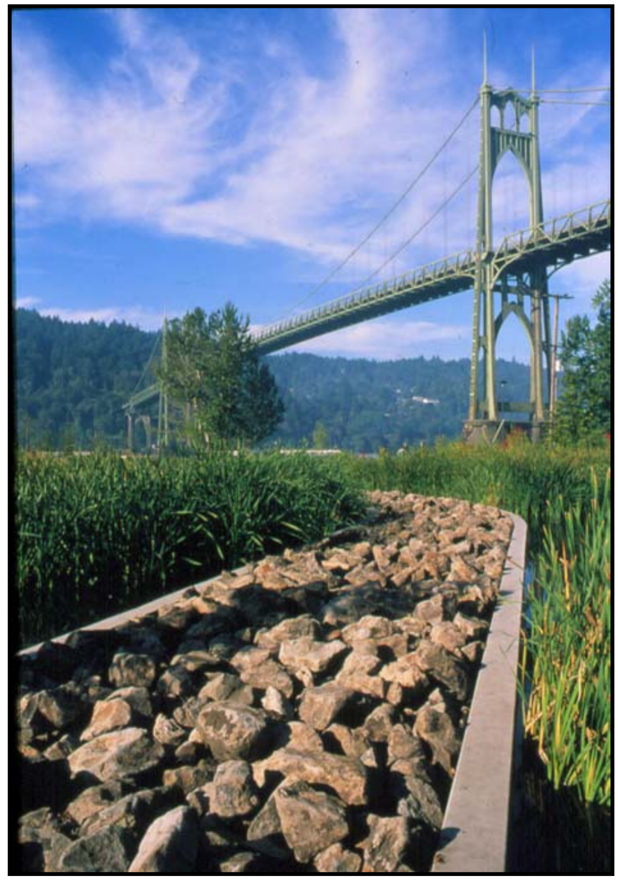


Figure I.6.27

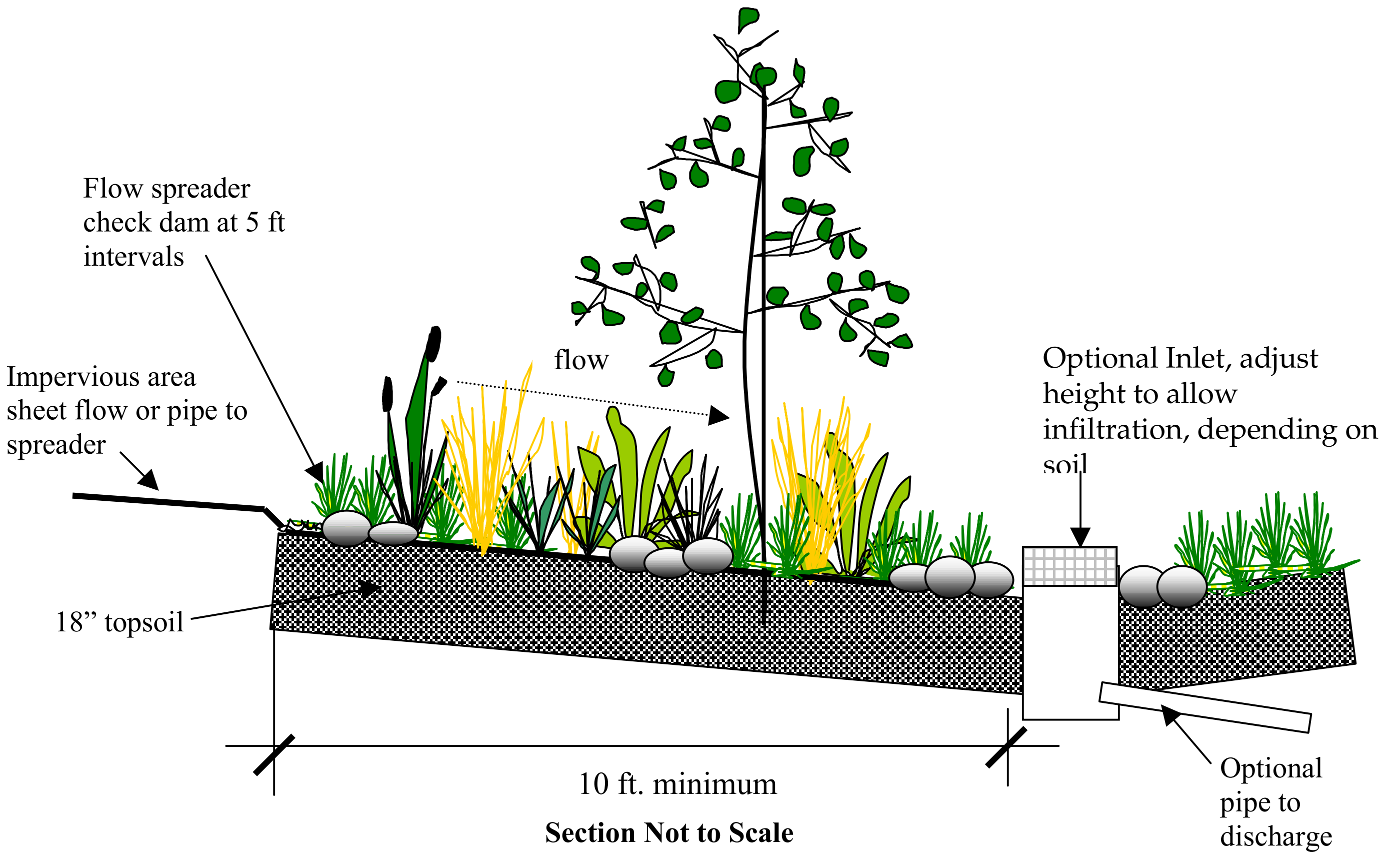
What have we learned? Pollutants and flow have been monitored for over two years for a total of 11 storm events. Generally, pollutant removal is good all year for most concentrations except cadmium, copper and zinc. Some of these pollutants are seeping in from sub-surface flows and surface flows during high intensity storm events. Phosphorous and nitrogen are also high on occasion. The pond remains wet all year, but summer discharges are small to non-existent Evaporation and soakage into surrounding soils is significant. Moderate amounts of excess irrigation water and unknown non-stormwater flows from the pipe system flow into the pond. However, since the pond doesn't have a constant summer flow the pond water occasionally becomes anaerobic and objectionable odors have been recorded. This problem remains to be addressed; one solution may be to drain the pond every summer. BES tried to accurately measure inflow, outflow and bypass, but the sub-surface and surface flows cannot be measured by the flow meter in the intake pipe. These uncontrolled sources also compromise the pollutant removal information. Education is needed in the neighborhood to reduce pollutants at their sources.

After construction an inspection of the diversion structure showed that the concrete dam had been installed in the wrong place and low flows were not entering the pond. The dam was immediately removed. It's very important to assure good design and construction quality control. Check the engineering and construction details. Concerns about warm season water temperatures impacting the river are still being investigated. However, the pond doesn't discharge very much in the warm season. Sediments are accumulating in the rock flume and vegetation is starting to grow. It has been decided to let this continue and try to determine if an un-maintained pond loses its efficiency. Aesthetic pruning will continue, however. Many undesirable and potentially hazardous materials have been removed from the pond. These have included hypodermic needles, rat poison, trash and debris. Use of a forebay to trap these things would have been desirable.

Another issue, the pond vegetation and presence of water has been attractive to wildlife. Ducks are always around and at least two families have nested there. The ducks sometimes feed in the bottom sediments where the pollutants are being trapped. It is yet to be understood whether this is a problem to the wildlife. Domestic dogs also like to play in the pond. Raccoons and other wildlife have been observed. Another note concerning fish and flooding. During the 1996 flood the pond became a backwater for the river flows. Carp and potentially other fish found the pond and as the flood receded found themselves isolated from the river. When the hot summer of 1998 occurred all the fish died. It is unknown whether any currently threatened species might have used the pond for refuge during the flood, but they surely could not survive the summer conditions. Designers should keep this is mind when proposing facilities near natural waterbodies.

Vegetative filters. Figure I.6.28 demonstrates the use of scuppers as roof runoff cascades to the Vegetative filter located on the southside and adjacent to the building. Most of the building has a metal roof of about 12,000 sf that directs flow into a gutter with several steel scuppers. These scuppers allow the runoff to freefall into the garden area below. Large stone and rock are at the impact point of each freefall to diffuse energy and spread the water into the plantings. Planters have a mixture of lush ornamental, native and wetland plants and are lined with crushed stone to provide a visually unique image year-round. Runoff is detained in the planters where some infiltration occurs. Large storm events have runoff that overflows to a catch basin.

Figure I.6.28



Section Not to Scale

Description *Vegetative filters are gently sloped areas. Stormwater enters the filter as sheet flow from an impervious surface or is piped and then converted to sheet flow using a flow spreader.*

Stormwater Management Function and Sizing *Flow control is achieved using the relatively large surface area and a generous proportion of check dams. Pollutants are removed through filtration and sedimentation. Using above proportions size at 0.6 x impervious area.*

General specifications *Acceptable for all soil types. Filters shall be a minimum of 20 ft. x 10 ft. Maximum slope is 10%. Plantings shall be in Check dams shall be of durable, non-toxic materials- i.e., rock, brick, and old concrete. Check dams shall be the width of the filter x 3-5” height. Filters designed using these criteria will not need to include a bypass of larger storms. Runoff shall enter the buffer as predominately sheet flow. Check dams and flow spreaders are required. Filters can be planted with a variety of trees, shrubs, and ground covers, including grasses. Freeboard not required.*

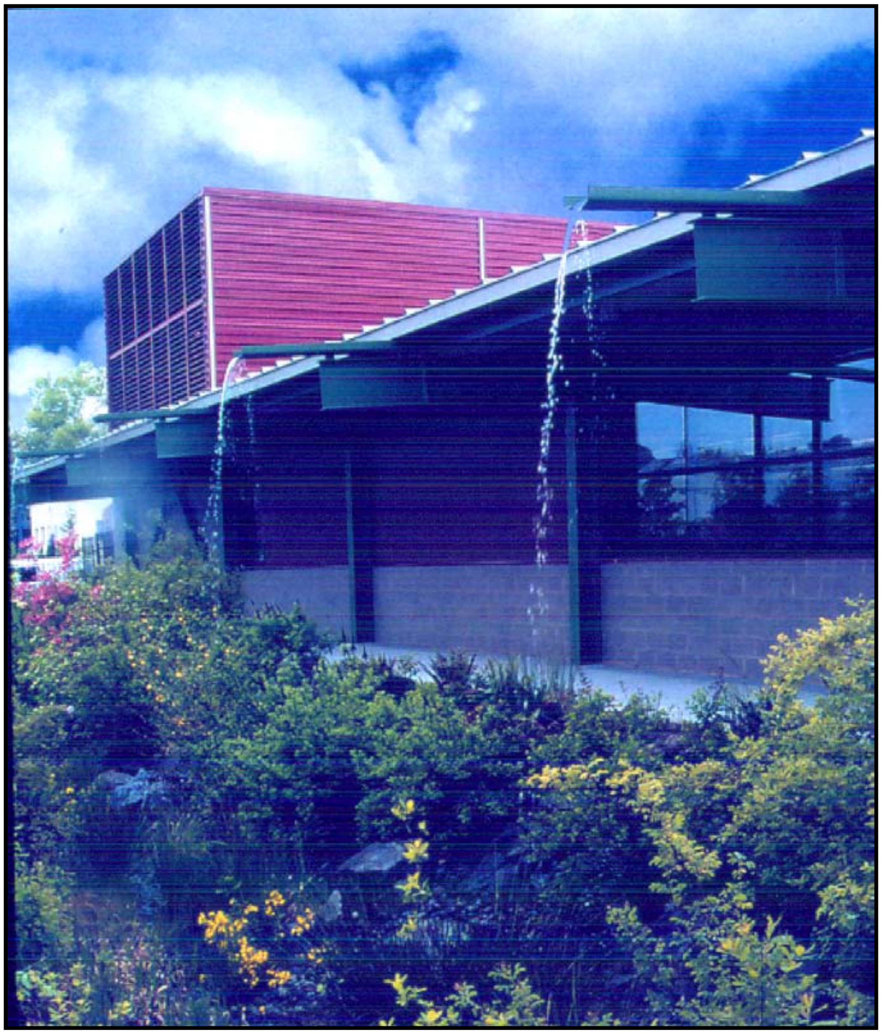


Figure I.6.29

What have we learned? It works great and looks good too. Unfortunately, the planting areas are unnecessarily deep to allow for a non-essential freeboard. If a failure occurred at the catch basin inlet the excess runoff would flow into the parking lot drains. An important reason to discontinue use of the freeboard, where they are not needed is to allow more surface area for runoff to spread within the planting areas. The addition of a few check dams and raising the inlet grate a few inches will help achieve this goal.

The Oregon Museum of Science and Industry (OMSI)

This is an 18-acre redevelopment site, with a 100,000 sf museum and exhibit space and parking lots for 700 cars. The project was Portland's first major demonstration of on-site parking lot stormwater management using 10 landscape swales to convey, infiltrate and filter runoff. These swales were used in place of the originally proposed, conventionally raised landscape medians. Based on visual observations, as the soil and vegetation "mature" significant infiltration now occurs and runoff is only associated with large storm events. (See Test swales above)

This project first came to the attention of the Portland Bureau of Environmental Services (BES) in 1990 when plans were submitted for review. At that time, neither the city of Portland nor the state of Oregon had specified site design requirements for stormwater quality discharges to the Willamette River. However, BES was gearing up to address forthcoming NPDES stormwater regulations and a Combined Sewer Overflow problem of significant proportions, so clean rivers were and still are, of concern. Following a review of the preliminary OMSI site plans, BES staff approached OMSI with the unprecedented request that it voluntarily redesign the parking lots and landscape to capture pollutants in stormwater runoff. The layout of the buildings and parking were not affected by this proposal. The BES suggestion was to adjust site grading and change the already proposed landscape medians to accept runoff rather than shed runoff.

OMSI was very interested in the environmental approach, but the non-profit organization was under a tight budget and timeline. They agreed to change the design on the condition that the existing schedule be met with no overall increase in costs. The OMSI consultant team determined that even with the redesign fees, the related construction cost savings would result in a net reduction of project costs. Taking the environmental approach would actually be less expensive to construct.

The parking lots were initially redesigned to include grass/turf swales to filter out pollutants as the runoff traveled through them. OMSI took this a step further and required the landscape architects to improve the design to detain water longer and to incorporate native and wetland vegetation. OMSI considered this "mini linear wetland" concept a more attractive and educational approach for their new facility. Interpretative signs were installed to educate the public about the benefits of the swales and wetlands in improving water quality. The city, for its part, had established a special team from various bureaus to assist in moving the project smoothly through the city approval process. This took an enormous effort as there were no existing policy or codes, which allowed developers to use water quality site design techniques.

Figure I.6.30 shows some of the restoration and pedestrian improvements along the Willamette River bank. The site's western boundary is along the riverfront which was stabilized with rock riprap and included intensive plantings of native riparian vegetation.

Landscape swales

Figure I.6.31 shows one of the ten swales. The swales are 6 ft wide and vary in length from 100 to 250 ft. for a total length of 2,330 ft. They were originally designed as bio-filters but have continued to exhibit good infiltration characteristics. Check dams were installed every 50 feet to slow the flows and encourage infiltration. The parking dimensions were modified to allow more space for plantings and minimize impervious surfaces. (Special approval was required, minimum stalls were 9 ft by 18.5 ft.) Stalls are 8-½ ft wide by 16 ft long with bumpers designed to overhang the curbs. Parking is at 90 degrees and the aisle is 24 ft wide. Recently the Portland city council approved a new parking lot code that allows 20 ft aisles and 9 ft by 16 ft stalls. Landscape space in front of the stalls is required at 6-8 ft width to allow for stormwater management. No parking spaces are lost as the code just provides more room for landscape and less for cars.

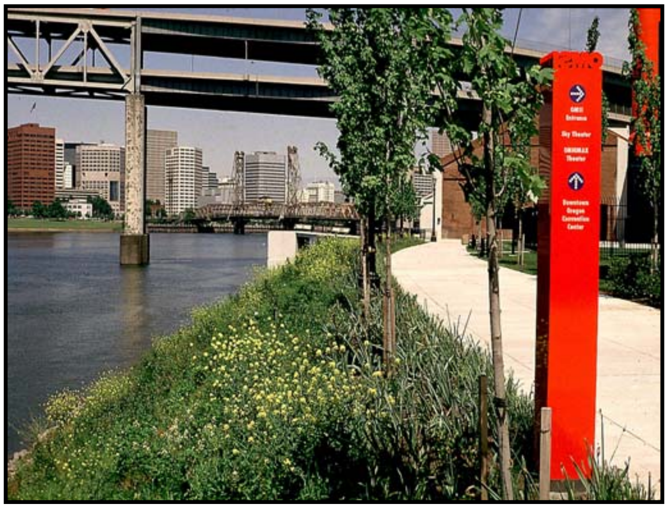


Figure I.6.30

Figure I.6.31

What have we learned? In 1996 the BES prepared a water quality audit and estimated that the bioswale system captures 50% of the average annual total suspended solids (TSS) loadings from the site. It was also estimated that with minor design improvements, such as additional check dams and more curb cuts, TSS capture would increase to 90% of the average annual site loading. Curb cuts were installed at 30 ft on center. Performance could be improved by installing curb cuts at 10 ft on center. These improvements have not been implemented because a major portion of the site was modified when a public street was constructed. Many of the improvements may still be made in the future. Visual observations continue to show that the swales allow much of the runoff to infiltrate.

Swale maintenance is incorporated into the normal operations of the site. The landscape medians were always intended to be a landscape feature of the site, which would require maintenance. The bioswales only require a little more attention. Curb cuts must be checked and cleared at least once a year. City staff have observed that some curb cuts were poorly constructed/located and need modification to reduce build up of sediments which block runoff from entering the swales. In hindsight now all swales were unnecessarily designed with 12” freeboards. Although, because the bioswales are oversized, it will take several decades before any accumulation of pollutants will need removal, if ever. The parking lot has significant use and lots of trash. Wind blows the trash into the swale vegetation where it is trapped. This has been considered a desirable aspect of the swales, as the trash is somewhat camouflaged until it is removed by OMSI staff.

The success of OMSI demonstrates that water quality and stormwater runoff measures can fit into constrained spaces, save construction costs, and have an attractive appearance. The owner documented that they saved about $78,000 in construction costs. These saving were achieved through the reduction of pipe, manholes and catch basins.

Custer Park

A small neighborhood park with playground, open lawn, and softball and soccer field. This was a 4-acre park renovation project, with high demand for a full size soccer field. Before the park was developed in the 1950's a small seasonal creek ran through the site. Several seasonal springs also contributed to the small creek flows. The original 1950's park design called for the piping of the creek to drain the springs and stormwater runoff from an adjacent residential neighborhood upland of the park.. The park's bureau desire was to have the water out of site and out of the way, but Parks has been struggling with wet turf ever since. In 1996-97 BES, Parks and Murase Associates worked with very little budget and redesigned the site to daylight a 400-foot section of piping. Appearing as a daylighted swale, it runs adjacent to a new pathway, and is planted with native hydrophytes and riparian shrubs and trees. A series of stone weirs slows the velocity of the flow, allowing sediment to drop out, while the plantings provide filtration. The swale terminates in a detention pond that removes much of the remaining pollutants from the flow. While the swale provides improved water quality, and makes visible those parts of the hydrologic cycle that are usually hidden, it also introduces habitat that is beneficial for wildlife and adds an additional layer of interest to park users. The completed project responds to the neighborhood desire to return nature to the park and provides a larger playing field as well.

Figure I.6.32

Landscape Swale

The site terrain has a grade change of 30 ft over a distance of 600 lineal ft. It was determined that only the city "water quality" storm event would be used to determine the bioswale design. These relatively small storm events would not pose as much risk to the park and the larger storms are allowed to continue to flow within the original pipe system. A diversion structure was installed to direct small storm flows into a swale cut into the slope along one side of the park. At the same time the soccer field was extended up to the edge of a pedestrian path that runs adjacent to the bioswale on the other side. Figure I.6.32 shows the swale from the down stream end looking up toward the park.

What have we learned? It works great and looks good too. Plantings were not sufficient to allow adequate coverage and establishment in the first two years but now are doing fine. The swale included an unnecessary 12" freeboard, which diminishes the aesthetics. Since the project is within an open area and there was a high flow diversion upstream the freeboard was over-designed. A positive aspect of the excessive depth of the swale is its capacity to accumulate sediment for many decades without the need for maintenance.

WRAP-UP

Water is the main theme of this chapter, but as many philosophies espouse, all things are connected. The essence of this chapter is to present techniques that help the urban environment function in a more natural way. The reason for doing such is to reduce negative impacts caused by human development. Although the case studies are within the city of Portland, the principles are universal and can be applied to any region. The success of these projects is proof that ecological design not only benefits the environment of humans and wildlife but it often costs less to implement and sustain. Perhaps, we can "have our cake and eat it too." It is no easy task however; many institutional barriers and professional mindsets must be overcome. Design, research, demonstration projects and education are all key elements in helping to bring these and other new approaches to the professional community.

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Disclaimer

The discussion in this chapter is not intended to substitute for professional advice applicable to specific project circumstances. Design approaches are offered to facilitate understanding of the concepts and must be considered in terms of the project, local building codes, and regional climate. Readers are urged to seek professional assistance before applying any of the techniques of this chapter. The techniques and other information presented may not represent the latest, approved approaches of the City of Portland, OR.